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USING WATER BALANCE TO ASSESS THE GROUNDWATER RECHARGE IN THE AREA BETWEEN RUTBA AND DHABAA, WESTERN OF IRAQ

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ABSTRACT

The study area is located in Al-Rutba city, Al-Anbar Governorate, western Iraq. The metrological data were collected during 1981 – 2016, and used to assess the climatic condition for the study area. The total annual rainfall was 113.3 mm and relative humidity was 47.1%, while the monthly average temperature was 20.1 °C, evaporation was 3074.3 mm, the wind speed was 2.6 m/s with a prevailing direction along the year was NW 29.2%. Data derived from the ratio of wind direction and sunshine duration was 9.2 h/day. The climate of the study area is described as an arid and relatively hot in summer, and cold with low rain in winter. During the 35 years' comparison period, the highest potential evapotranspiration value was 175.82 mm during July and August, while the lowest value was 7.758 mm in January, while the total amount was 970.612 mm. The highest value of the corrected evapotranspiration was 212.74 mm in July and the lowest value was 6.78 mm in January, while the total amount was 1072.021 mm. Water surplus was recorded in the study area was 19.849% of the total rainfall which was equivalent to 113.3 mm. The study area consisted of a thin layer (<0.1 m) of sandy soil, therefore, this thin layer was not considered. A number of key findings are presented which pertain to; the type of rainfall event, wind conditions, and the location. Hence, the value of groundwater recharge was 22.489 mm with a rate of 19.849% which represents the percentage of groundwater recharge from the total rainfall.

Keywords: West Iraq; Classification of climate; Water balance; Potential evapotranspiration; Groundwater recharge

INTRODUCTION

There are a great number of different types of rainfall events, which vary hugely according to factors such as latitude, temperature, geography, atmospheric conditions etc. The study area is located in Al-Anbar Governorate, western part of Iraq. Also located within the western part of upper wedian between Rutba and Dhabaa. It represents part bordered by longitudes 40° 15' 36" E – 40° 32' 24" E and latitudes 33° 00' 36" N – 33° 04' 12" N. The total area is expanded over about 174.87 Km^2 with an elevation ranges 585 – 645 m above sea level (a.s.l.) (Fig. 1). Climate plays an important role in influencing the relationship between rainfall and evaporation that contribute to recharge groundwater. Its vary from one season or year to another, where the basic factors in the hydrological cycle are rainfall and evaporation. The climate has a clear effect on the abundance of water, whether surface water or groundwater and their applicability to different uses. The hydrological management of an area is fundamentally dependent on the climate and topographic of the region, where the climate is controlled by a particular region’s latitude and altitude. The precipitation is the main input parameter in the water balance of the study area, while discharge from wells and evapotranspiration are major output parameters. Another contributor to consumption of water in wetlands may include evaporation from vegetation-covered earth surface (Knapp, 2003). The study area was characterized by a number of exposed formations, they are: Zor Hauran Formation, Ubaid Formation, Mauddud – Nahr Umr Formation, Rutba Formation, Ms'ad Formation and Hartha Formation, in addition to Quaternary sediments, while subsurface extension, it's Ga'ara Formation and Mulussa Formation, where it is revealed in the north of the study area in Ga'ara Depression (Sessikian and Mohammed, 2007). The study area crossed by intermittent valleys formed by differential weathering and erosion resulted plateau surfaces with pediment sediments on their edges. The aim of this study is to determine climatic water balance by analyzing the climatic parameters of Rutba Meteorological Station for period 1981 – 2016, and percentage of groundwater recharge from the total rainfall.

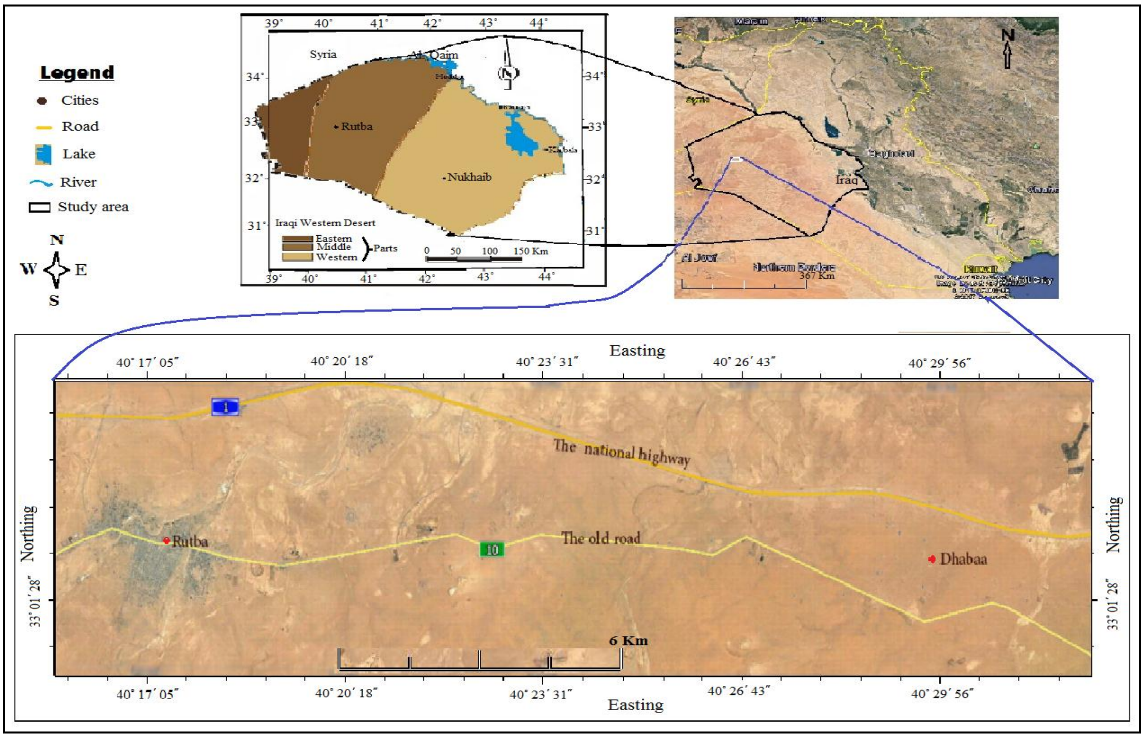

Fig. 1: Location map of the study area, Western Desert modified from (Sessikian and Mohammed, 2007)

MATERIALS AND METHODS

The meteorological data for the study area were taken from the Iraqi Meteorological Organization (2017) based on Rutba meteorological station during 1981 – 2016 with a gap between 2012 – 2015 in some of the metrological records. To estimate the missing records, the missing equation developed by Chien and Clayton (1980) was used and to assess the climatic condition in the studied area. The evapotranspiration was calculated monthly by using the Thornthwiat method. Two methods were used in the study area to determine the type of the prevailing climate. Lerner method was used to compute the water balance. Soil Conservation Service Method (SCS) that used the runoff curve number (CN) method was utilized to estimate runoff from storm rainfall. Then, the value of groundwater recharge was calculated in the study area.

RESULTS AND DISCUSSION

The climatic elements studies have identified six main variable elements. These elements are Rainfall (mm), relative humidity (%), temperature (°C), evaporation (mm), wind speed (m/s) and sunshine duration (h/day). The description of the variable climate elements utilized during the studied period 1981 – 2016 was mentioned as below:

1. Rainfall (P)

Rainfall plays a major rule on the hydrological cycle, especially in the arid and semiarid areas. It's the main source of growth or lack of agriculture in some areas (Wilson, 1971). Rainfall varies monthly and yearly, where the wet period which extends from October (11.5 mm) and continues to May (8.2 mm), the maximum rainfall was recorded in February (22 mm). The drought extends from June (0 mm) to August (0 mm) (Table 1).

2. Relative Humidity (RH %)

Relative humidity is a manifestation of atmospheric humidity, which is the ratio of the actual vapor pressure in a certain volume of air to the saturation vapor pressure at the same temperature (Shaw, 1999). In the study area, the maximum monthly average is (70.8%) in January and the minimum is (26.7%) in July, while the annual average of relative humidity is (47.1%) (Table 1).

3. Temperature (T)

Temperature is the main element of the climate, its dependent upon latitude, nature of the surface, altitude, and prevailing winds. There are many factors that contributed to the temperature degradation such as the development of industries and the population in addition to greenhouse gases (UNEP, 2000). The average temperature of the period 1981 – 2016 in Rutba station was high in summer season (June, July, August and September). The highest degree of the monthly average temperature has been recorded in July and August, which were 31.6 °C. The monthly average temperature drops during winter season (December, January and February). The lowest degree of the monthly average was 7.6 °C recorded in January (Table 1).

4. Evaporation (E)

Evaporation is defined as the process of transforming water from liquid to gaseous (Shaw, 1999). The monthly average evaporation in Rutba station for the period between 1981 – 2016 increases during summer season (June, July, August and September) the highest rate is recorded in July (498.8 mm), while evaporation rate decreased during the winter season (December, January and February). The lowest rate was recorded in December 74.5 mm (Table 1).

5. Wind Speed (WS)

The wind speed increase with the high temperatures and thus increasing evaporate soil water (Viessman and Lewis, 2007). Wind speed is increasing in the flat areas, and the rotation of the earth affects their directions. The wind speed ranged from 1.9 to 3.5

is the highest speed was recorded in summer season (June, July and ugust). July has the highest average wind speed 3.5 m/sec. The average wind speed drops during the winter (November, December and January). November has the minimum average wind speed 1.9 m (Table 1).

Depending on the ratio of wind direction within the studied period, the prevailing direction along the year was "NW" with 29.2% then follow it by "W" direction 19%, "E" direction 8.2%, "N" direction (8.1%), "SW" direction 6.1%, "SE" direction 5.2%, "NE" direction 5% and "S" direction 4.2%. While about 15% represents the state of stillness of the wind.

6. Sunshine duration

The sunshine duration means the number of hours of sunshine in one day (Chow, 1964), the temperature effect, relative humidity and evaporation. Sunshine rates vary at the station from month to month during the study period, as it reached maximum sunshine duration occurs in July with monthly average of 12.3 hour/day, while the minimum monthly average was 6.5 hour/day occurs during December and January, and the annual average was 9.2 hour/day (Table 1).

Table 1: Mean monthly records of climatic parameters at Rutba meteorological station during the years 1981 – 2016 (Iraqi Meteorological Organization, 2017)

Months	Rainfall (mm)	Relative humidity (%)	Temp. (°C)	Evaporation (mm)	Wind Speed (m/s)	Sunshine duration (h/day)
Oct.	11.5	44.5	22.2	222.9	2	9.1
Nov.	14.1	60.1	14.3	116	1.9	7.6
Dec.	16.1	70.7	9.4	74.5	2.1	6.5
Jan.	12.6	70.8	7.6	78.5	2.3	6.5
Feb.	22	62.7	9.5	109.4	3.2	7.4
Mar.	16.8	54.9	13.4	171.9	3.2	8.1
Apr.	11.7	42.4	19.5	251.2	3	8.7
May	8.2	34.9	24.8	344.7	2.9	9.9
Jun.	0	31.7	29.1	426.3	3.1	12.2
Jul.	0	26.7	31.6	498.8	3.5	12.3
Aug.	0	29.2	31.6	449.2	2.6	11.7
Sep.	0.3	37.2	28.1	330.9	2.1	10.5
Total	113.3			3074.3		110.5
Average	------	47.1	20.1	------	2.6	9.2

Figure (2) shows the various relations between all the mentioned climatic elements in the study area. The rainfall occurs during the months from September to May, while no rainfall during the rest of the year. The rainfall curve has an inverse relation with temperature, evaporation and sunshine duration while direct relationship with relative humidity has observed. The highest temperature, evaporation and sunshine duration values occurred during summer season from June to August, and the lowest values occurred during the rainfall season.

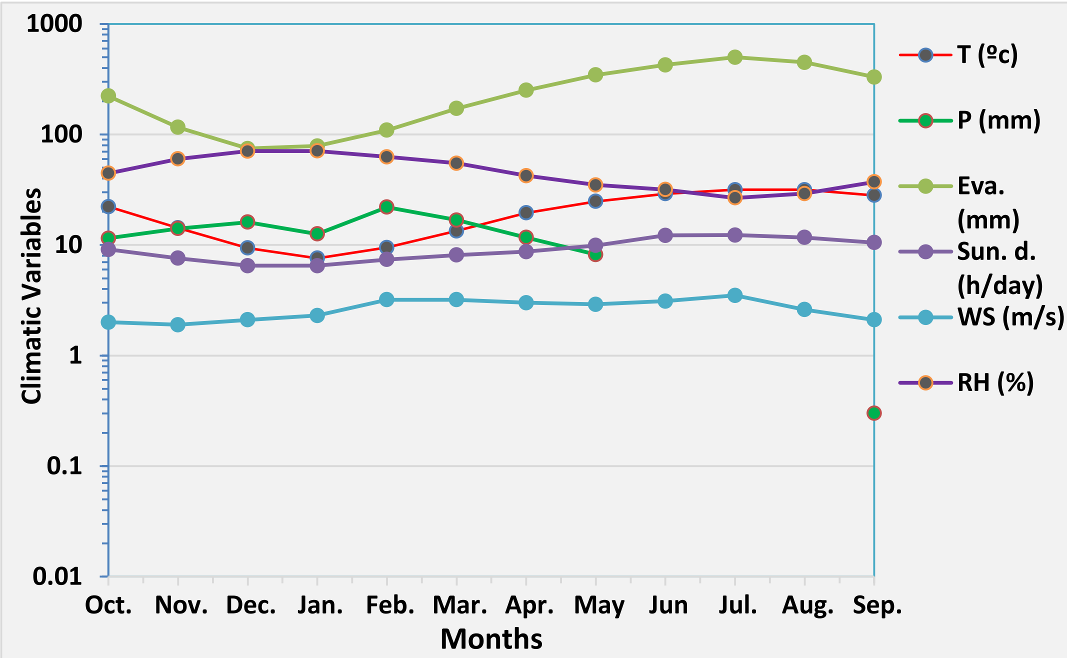

Fig. 2: The relationship between climatic variables in the study area

CLASSIFICATION OF CLIMATE

According to (Ketanah and Gangopadhyaya, 1974), the climatic data of the study area for the period 1981–2016 was classified. The type of the dominated climate during the months of the year of the study area was found to be humid to very dry, as shown in Table (2).

While the climatic classification suggested by (Al-Kubaisi, 2004), the values of AI-1 and AI-2 becomes as follows:

AI-1 = (1 × 113.3) / (11.525 × 20.1) = 0.489

$$AI\text{-}2 = \frac{2*\sqrt{113.3}}{20.1} = 1.059$$

Table 2: Climatic classification for the period (1981 – 2016) according to (Ketanah and Gangopadhyaya, 1974)

Months	P (mm)	PEc (mm)	H.I	Kettaneh and Gangopadhyaya, 1974
Oct.	11.5	78.5	0.2	Moderate to dry
Nov.	14.1	26.6	0.5	Moist
Dec.	16.1	10.6	1.5	Humid
Jan.	12.6	6.8	1.9	Humid
Feb.	22	10.8	2.04	Humid
Mar.	16.8	27.7	0.6	Moist
Apr.	11.7	65.9	0.2	Moderate to dry
May	8.2	119.9	0.07	Very dry
Jun.	0	173.210	0	Very dry
Jul.	0	212.740	0	Very dry
Aug.	0	200.430	0	Very dry
Sep.	0.3	138.680	0.002	Very dry

By comparing the values of AI-1 and AI-2 to the climate condition presented in Table (3), the dominant climate in the study area according to AI-1 was sub-arid to arid, while it is classified as sub-arid climate according to AI-2.

Table 3: Climate classification according to (Al-Kubaisi, 2004)

Type.1	Evaluation	Type.2	Evaluation
AI-1>1.0	Humid to moist	AI-2>4.5	Humid
		2.5 <AI-2< 4.0	Humid to moist
		1.85<AI-2<2.5	Moist
		1.5<AI-2<1.85	Moist to sub arid
AI-1<1.0	Sub arid to arid	1.0 ≤ AI-2<1.5	Sub arid
		AI-2<1.0	Arid

Evapotranspiration

The evapotranspiration in the study area was calculated monthly using the equation, which, derived by Thornthwait (1948).

$$PE = 16\,[10t / J]^{a} \quad \text{mm/month} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 1$$

Where (PE) Potential evapotranspiration (mm). (t) Mean monthly air temperature (°C). (J) Annual heat index (°C). (a) Constant.

$$J = \sum_{j=1}^{12} j \quad (\text{for the 12 month}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ 2$$

$$j = [tn / 5]^{1.514} \quad (\text{for each month}) \quad \ldots\ldots\ldots\ldots\ldots\ 3$$

Where (j) Monthly temperature parameter (°C). (n) Number of monthly measurement.

$$a = 0.016\,J + 0.5 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 4$$

After PE values are extracted, correct evapo-transpiration (PEc) values can be calculated from the following equation:

$$PEc = K^{*}\,PE \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 5$$

Where (PEc) Correct evapo-transpiration (mm). (K) correction coefficient related to hours between sunrise and sunset in the month.

$$K = DT/360 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 6$$

Where (D) number of days in the month. (T) an average number of hours between sunrise and sunset in the month. (K), represents the correction coefficient, which is extracted for each month from Rutba meteorological station, the location at latitude 33° 02' 06.7" N.

The values of PE and the PEc according to the equation (1) and (5), respectively, was determined, where the results presented in Table (4). The highest value of the PE was 175.82 mm in July and August, and the lowest value was 7.758 mm in January, while the total PE was 970.612 mm. The highest value of the PEc was 212.74 mm in July and the lowest value was 6.78 mm in January, while the total amount was 1072.021 mm.

Table 4: Mean monthly values of evapotranspiration for the period (1981 – 2016) at Rutba meteorological station, values calculated using Thornthwaite method

Months	Temperature t (°C)	j	PE (mm)	K	PEc (mm)	Evaporation (mm)
Oct.	22.2	9.6	81.14	0.97	78.54	222.9
Nov.	14.3	4.9	30.97	0.86	26.63	116
Dec.	9.4	2.6	12.35	0.86	10.62	74.5
Jan.	7.6	1.9	7.76	0.87	6.78	78.5
Feb.	9.5	2.6	12.65	0.86	10.81	109.4
Mar.	13.4	4.5	26.86	1.03	27.66	171.9
Apr.	19.5	7.9	61.08	1.08	65.96	251.2
May	24.8	11.3	103.42	1.16	119.96	344.7
Jun	29.1	14.4	146.79	1.18	173.21	426.3
Jul.	31.6	16.3	175.82	1.21	212.74	498.8
Aug.	31.6	16.3	175.82	1.14	200.43	449.2
Sep.	28.1	13.7	135.96	1.02	138.68	330.9
Total		J=105.8	970.61		1072.02	3074.3

Water Balance

The water balance of the study area calculated by using Lerner *et al*. (1990) method.

- **Water Surplus (WS)**

$$WS = P - PEc \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 7$$

$$PEc = APE, \text{ when } P > PEc$$

Where (WS) Water Surplus (mm). (P) Rainfall (mm). (PEc) Corrected evapotranspiration (mm). (APE) Actual Evapotranspiration (mm).

- **Water Deficit (WD)**

$$WD = PEc - P \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 8$$

$$P = APE, \text{ when } P < PEc.$$

Where (WD) Water Deficit (mm).

The total annual value of WS was 22.489 mm from total rainfall, which was recorded in December, January and February due to the rainfall exceeds PEc. The WS ratio from the yearly rainfall can be represented as:

$$WS\ \% = WS/P \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 9$$

$$WS\ \% = 22.489 / 113.3 \times 100 = 19.849\%$$

While the water deficit (WD) ratio can be represented as:

$$WD\ \% = 100 - WS\ \% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 10$$

$$WD\ \% = 100 - 19.849 = 80.151\%$$

Table (5) shows the monthly averages of APE, WS and WD and Figure (4) shows the relationship between the mean monthly of rainfall (P) and corrected evapo-transpiration (PEc), which shows the water surplus (WS) and water deficit (WD) periods.

Table 5: Water surplus and water deficit for the study area

Months	P (mm)	PEc (mm)	APE (mm)	WS (mm)	WD (mm)
Oct.	11.5	78.54	11.5	0	67.04
Nov.	14.1	26.63	14.1	0	12.53
Dec.	16.1	10.62	10.6	5.48	0
Jan.	12.6	6.78	6.8	5.82	0
Feb.	22	10.81	10.8	11.19	0
Mar.	16.8	27.66	16.8	0	10.86
Apr.	11.7	65.96	11.7	0	54.26
May	8.2	119.96	8.2	0	111.76
Jun.	0	173.21	0	0	173.21
Jul.	0	212.74	0	0	212.74
Aug.	0	200.43	0	0	200.43
Sep.	0.3	138.68	0.3	0	138.38
Total	113.3	1072.02		22.489	981.21

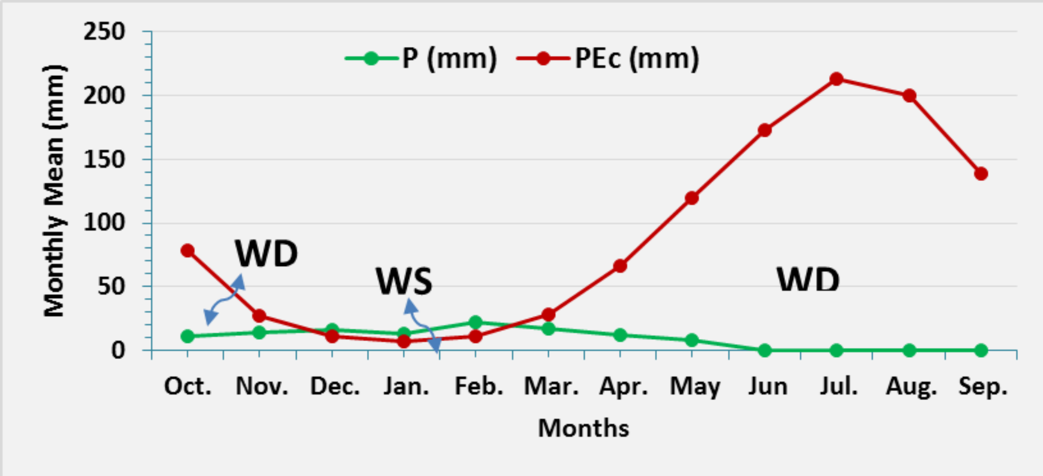

Fig. 4: The relationship between mean monthly values of rainfall and corrected evapotranspiration in the study area for the period (1981 – 2016)

Soil Conservation Service Method (SCS) is used the runoff curve number (CN) method, to estimate runoff from storm rainfall. The Natural Resources Conservation Service (NRCS), by U.S. Department of Agriculture has developed the curve-number model (USDA, 1986). It is the widest method for estimating rainfall excess, by the following formula:

$$Q = \frac{(P - I_a)^2}{(P + I_a) + S} \quad P > 0.2\ S \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 11$$

Where (Q) Runoff (mm). (P) Total rainfall (mm). (S) maximum potential retention after runoff (mm). (I_a) = initial abstraction (mm). (I_a) can be approximated by the following empirical equation:

$$I_a = 0.2\ S \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 12$$

$$CN = \frac{1000}{10 + S/25.4} \quad (S) \text{ in (millimeter)} \ \ldots\ldots\ldots\ldots\ldots\ldots\ 13$$

CN was determined using two Tables (6 and 7) provided by (USDA, 1986), CN calculated by the following formula:

$$CN = A1CN1 + A2CN2 + \ldots\ldots + An\ CNn \,/\, A1 + A2 + \ldots\ldots + An \ \ldots\ldots\ldots\ 14$$

Where:

A1 + A2 + ……. + An are the areas of various urban land uses.

CN1, CN2..., CNn is the curve numbers.

According to a study by Buringh (1960) and Osama *et al*. (2014), the soils in the study area consist of sand. Therefore, according to these specifications, the type soil of study area is of class A. According to formula 14, the CN for this soil condition is equal to 61, as shown in Table (8). Whereas the amount of Rs was zero, which reflects that the soils have low runoff potential and high infiltration rates even when thoroughly wetted, as shown in Table (9). Therefore, based on the data obtained from this method, the total WS is representing the groundwater recharges. It is worth mentioning, that the runoff in the intermittent valleys is the result of the transport from long distances outside recording Rutba meteorological station.

Table 6: Classification HSG according to the texture of the new surface soil (USDA, 1986)

HSG	Soil textures
A	Sand, loamy sand, or sandy loam
B	Silt loam or loam
C	Sandy clay loam
D	Clay loam, silty clay loam, sandy clay, silty clay, or clay

Table 7: Curve number for various urban land uses (USDA, 1986)

Cover type and hydrologic condition	Curve number for hydrologic soil group			
	A	**B**	**C**	**D**
Poor condition (grass cover < 50%)	68	79	86	89
Fair condition (grass cover 50% to 75%)	49	69	79	84
Good condition (grass cover > 75%)	39	61	74	80
Paved parking lots, roofs, driveways, etc.	98	98	98	98
Paved; curbs and storm sewers	98	98	98	98
Paved; open ditches	83	89	92	93
Gravel	76	85	89	91
Dirt	72	82	87	89
Natural desert landscaping	63	77	85	88
Artificial desert landscaping	96	96	96	96
Commercial and business	89	92	94	95
Industrial	81	88	91	93
Residential districts by average lot size:				
1/8 acre or less (town houses)	77	85	90	92
1/4 acre	61	75	83	87
1/3 acre	57	72	81	86
1/2 acre	54	70	80	85
1 acre	51	68	79	84
2 acres	46	65	77	82

Table 8: Curve number for various urban land uses for the study area

Cover type and hydrologic condition	Area Km^2	CN	CN x Area
Fair conditions: grass cover on 50% to 75% of the area	65	49	3185
Poor conditions: grass cover on 50% or less of the area	101.370	68	6893.160
Urban area	8.500	77	654.500
Total	174.870		10732.660
CN			61

Table 9: Mean monthly values of surface runoff in the study area

Months	P (mm)	WS (mm)	Weighted CN	S	P > 0.2 S	Rs (mm)
Oct.	11.5	0		0		0
Nov.	14.1	0		0		0
Dec.	16.1	5.48		162.39	No	0
Jan.	12.6	5.82		162.39	No	0
Feb.	22	11.19		162.39	No	0
Mar.	16.8	0		0		0
Apr.	11.7	0		0		0
May	8.2	0		0		0
Jun.	0	0	61	0		0
Jul.	0	0		0		0
Aug.	0	0		0		0
Sep.	0.3	0		0		0
Total	113.3	22.489				0

According to a study of Al-Dulaymi *et al*. (2012), the soil thickness in the study area is about 0.1 m and is considered as a thin layer. In addition to the soil type, it is sandy and very thin, so the soil moisture can be neglected in calculations, (the soil moisture assumption is zero), thus, the value of groundwater recharge in the study area can be estimated from the following equation:

$$WS = Rs + Re \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 15$$

Where (WS) Water Surplus (mm). (Rs) Surface runoff (mm). (Re) Groundwater recharges (mm).

Based on the record of the Rutba meteorological station for the period (1981 – 2016), the amount of rainfall is observed to be low, and with taking into consideration the soil type, the surface runoff will be absent in the study area.

Re = 22.489 – 0 , Re = 22.489 (mm)

Re% = (22.489 /113.3) *100 = 19.849%, represents the percentage of groundwater recharge from the total rainfall.

The value of groundwater recharge during a water year in the study area can be calculated from the following equation:

$$Re_{annual} = A \times Re \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 16$$

Where (A) Area of study (174.87) Km^2.

$Re_{annual} = 174.87 * 10^6 (m^2) * 22.489 * 10^{-3} (m)$

$Re_{annual} = 3.9326 * 10^6 m^3/year$.

CONCLUSIONS

- By conducting analyzes and calculating the annual averages of the climatic parameters, it is shown that the total annual rainfall was 113.3 mm and relative humidity was 47.1%, while monthly average temperature was 20.1 °C, evaporation was 3074.3 mm, wind speed was 2.6 m/s with prevailing direction along the year was "NW" 29.2%. Data derived from the ratio of wind direction and sunshine duration was 9.2 h/day.
- In general, the climate of the study area is found to be located in the region of sub-arid to arid-sub arid, which described as relatively hot in summer and cold with low rain in winter.
- The total annual value of water surplus (WS) is (22.489 mm) from total rainfall. Where the water surplus (WS) ratio from the yearly rainfall is (19.849%), while the water deficit (WD) ratio is (80.151%).
- Value of groundwater recharge represent (22.489 mm) with a rate (19.849%) represents the percentage of groundwater recharge from the total rainfall.

REFERENCES

Al-Dulaymi, A., Al-Heety, E. and Hussien, B., 2012. Geo-Electrical Investigation of Mullusi Aquifer, Rutba, Iraq. International Jour. of Geosci., 3: 549 – 564.

Al-Kubaisi, Q.Y., 2004. Annual aridity index of type .1 and type .2 mode options climate classification, Journal of science, 45c(1): 32 – 40.

Buringh, 1960. Soils and soil conditions in Iraq. Republic of Iraq, ministry of agriculture, Baghdad, 322pp.

Chien, S.H. and Clayton, W.R., 1980. Application of Elovich equation to the kinetics of phosphate release and sorption in soil. Soil Science, soc Am, 44: 265 – 268.

Chow, V.T., 1964. Handbook of applied hydrology. A compendium of water resources technology McGraw. Hill Book Company, New York, 1454pp.

Iraqi Meteorological Organization (IMO), 2017. Climatically Data for Rutba meteorological station for the period (1981 – 2016), Baghdad, Iraq.

Ketanah, M.S. and Gangopadhyaya, M., 1974. Analysis rainfall data in II.R.I, drainage principles and investigati0n, P.O. box 45, Wageninyen, the Netherlands, 368pp.

Knapp, H.V., 2003. Evaporation and Transpiration, Handbook of Applied Meteorology, edition. 1, New York, 537 – 554.

Lerner, N. D., Issar, A.S. and simmers, I., 1990. Groundwater Recharge-A guide to understanding and estimating natural recharge, International Association of Hydrogeologists, Kenilworth, Rep. 8, 345pp.

Osama T.A., Mohammed M.A. and Thaer K.J., 2014. The Relationship between Rainfall and Soil Moisture. Diyala Jou. for Pure Sciences, 11(2): 9 – 25.

Sessikian, V.K. and Mohammed, B.S., 2007. Stratigraphy of the Iraqi Western Desert. Iraqi Bull. Geol. Min., 51 – 124.

Shaw, E.M., 1999. Hydrology in practice. 3rd Ed. Stanley Thornwaites Publ. U.K. 569pp.

Thornthwait, C.W., 1948. An Approach toward a Relation Classification of Climate, Geographical Review, vol.32, 55pp.

UNEP, 2000. Global warming environmental, report. 2000.

USDA (United State Department of Agriculture), 1986. Urban Hydrology for small watersheds. Natural Resources Conservation Service, Conservation Engineering Division Technical Release 55, Washington, D.C.

Viessman, W.J. and Lewis, G.L., 2007. Introduction to Hydrology, 5th ed., Person Education, Inc. and Dorling Kindcrsly, Inc. India, 612pp.

Wilson, E.M., 1971. Engineering hydrology. McGraw-Hill Press. Ltd., 182pp.